THE PERFECT EYE

APPLICATION NOTE

AN015

Topic:

Glossary

Summary:

This document contains an explanation of terms commonly used in connection with Photonfocus products.

CONTENT

1. Introduction

This document contains an explanation of terms commonly used in connection with Photonfocus products.

2. Glossary

A

ADC	See *Analog to Digital Converter*
Analog to Digital Converter	A device which converts an analog voltage or current signal to a discrete series of digitally encoded numbers (signal) for computer processing.
API	Abbreviation of Application Program Interface, a set of routines, protocols, and tools for building software applications. Photonfocus supplies an API for the control of the cameras.
Area Camera	A camera with pixels in both rows and columns, forming an array which produces a 2D image.
Area of interest	See *Region of Interest*

B

Bayer pattern	A mosaic pattern that uses red, blue and green filters to make up the image, sometimes described as a Colour Filter Array. The actual colour of a pixel can be calculated by the Bayer algorithm from the intensity levels of the neighbouring different coloured pixels.
Blooming	Blooming is a common problem for CCD sensors but not for CMOS sensors. At high light levels it is possible to exhaust the storage capacity of the CCD well. Excess carriers can then spill over into adjacent pixels and degrade the accuracy of the signal. Typically this results in a bright halo around bright parts of the image and loss of detail.

C

Camera Control Signals	In CameraLink, signals which can be specified by the camera manufacturer to control camera specific settings, e.g. an external trigger.
CameraLink	Hardware specification for high speed data transfer between one or more cameras and a frame grabber with data rates

	up to 1.9 GBit/s in base mode or up to 5GBit/s in full mode.
CC1, CC2, CC4, CC4	CameraLink Camera control signals. See *Camera Control Signals*.
CFR	See *Constant Frame Rate*
Clser.dll	CameraLink API to the serial interface between a frame grabber and a camera.
Cluster	A group of two or more defect pixels, located close to each other. Typically close is defined as touching, though other definitions are possible defining a minimum distance between the pixels.
C-Mount	Short for Cine-mount. Standard machine vision lens mount. 1-inch diameter, 32-thread/inch screw-in mount. Produces a focal plane 17.52 mm behind the camera's flange.
Constant Frame Rate	In this mode the camera delivers frames with a constant, configurable frame rate.

D

DAC	See *Digital to Analog Converter*
DAC	Digital to Analog Converter
Dark current	Charge detected by the photodetector without illumination. Dark current increases with increasing temperature, approximately doubling every 8 Kelvin. Dark current degrades the detection of very small optical signals since the statistical noise of dark current electrons becomes comparable to the small optical signal.
Dark current saturation time	Integration time in which the photo detector reaches saturation in the absence of light, i.e. due only to dark current.
Dark signal	Signal generated by the dark current in a specified integration time, at a given temperature.
Defect pixels	Pixels whose response to light is outside of the acceptable range. Typically these appear as lighter spots in the image, but dark spots are also possible (see also *Hot pixels*)
Depth of field	Refers to the distance between the closest and farthest sharp or in-focus portion of a photograph (also called the focal range). A smaller *f-stop* (e.g. F1.2) will create a shallow depth of field; a larger f-stop (e.g. F11) will create a greater depth of field.
Digital Number	The grey level output from a digtal camera (See *ADC*).

Digital to analog converter	A circuit used to convert digital numbers into analog signals. Compare with *ADC*.
DLL	Dynamic Link Library. A collection of executable functions or data that can be used by a Windows application. For example, *PFRemote* provides a DLL to control the camera settings.
DN	See *Digital number*
Dynamic range	Relation between the optical energy creating the saturation signal and the smallest detectable optical signal above noise or quantisation step within one frame, i.e. all pixels with the same integration time and gain. This measurement differs from the indication of signal to noise ratio, since nonlinear compression is often used to boost dynamic range. Also some camera manufacturers take only quantisation step and not noise into account giving artificially high dynamic range figures.

E

EEPROM	Electrically Erasable Programmable Read Only Memory. A non-volatile storage device which can be reprogrammed electrically during system operation.
Electronic shutter	An electronic system in the sensor used to control the amount of time the device is sensitive to light. Compare to *global shutter*, *rolling shutter*.
Exposure Time	Image sensors integrate charge over the so called exposure or integration time. This time defines the response of the sensor to the impinging radiation. The shorter the integration time, the smaller the signal the sensor produces at a given radiation intensity. The integration time is controlled by the *electronic shutter*.
EXSYNC	External Synchronisation. External Trigger signal. In the EXSYNC mode the camera is fed with a trigger signal which generated either on the frame grabber or which is provided externally to start the integration of an image. Depending on the trigger mode, the exposure time can be set by software (*PFRemote*), by the length of the trigger pulse or by a separate signal (see *Extern Sync*).
Extern Sync	External synchronisation mode. See *EXSYNC*, *Trigger*.

F

FEN	In CameraLink, Frame enable. See *Frame valid*
FFD	See *Flange Focal Distance*.
Fill factor	Fill factor is the relation between the light sensitive area of a pixel matrix and the area covered by readout and control electronics. It is the proportion of the pixel area which captures a useful light signal.
Flange Focal Distance	Distance from the lens flange mounting surface to the image plane at infinity focus.
F-number	F-numbers are a measurement of the size of the hole that the light passes through in the rear of a lens, relative to the focal length of the lens. The smaller the f number, the more light gets through the lens. Each additional "f stop" means that half as much light gets through the lens. So, at f/2, twice as much light gets through the lens as when you set that same lens at f/2.8.
FPN	Fixed pattern noise describes all components of temporally invariant offsets, nonlinearities, gain errors, matching errors etc. of individual pixels. Fixed pattern noise is not a “true” noise source since it can be largely corrected by subtraction and multiplication of a correction matrix (gain-offset correction).
fps	Frames per second
Frame	One complete image in a picture sequence.
Frame grabber	A device that interfaces with a camera and stores the received image in the internal memory or in the computer memory. It typically provides basic image pre-processing such as bayer pattern calculation, shading correction, LUT, filtering.
Frame rate	Frame rate is the repetition frequency at which frames are acquired and is measured in fps (frames per second). The maximum frame rate is 1/frame time. See frame time.
Frame time	The time used to acquire and read out a complete image. The frame time consists of exposure time, readout time, and minimum reset time plus any delay times that may be required for proper sensor operation.
Frame valid	In CameraLink, a handshaking signal that indicates whether or not the camera is outputting a valid frame of data.

Free Running	Default camera mode, where the camera is master and constantly delivers images to the frame grabber at a preset frame rate.
Full well capacity	The amount of light that can be detected before a pixel saturates at full white. This is typically measured in electrons and has implications for dynamic range, *temporal noise* and sensitivity. Higher full well typically gives bigger dynamic range and better noise performance at the expense of reduced sensitivity. Choice of full well capacity is therefore always a compromise.
FVAL	CameraLink signal. See *Frame valid*

G

Global shutter	Global shutter is a type of *electronic shutter* which operates on all pixels at the same instant giving a true "snapshot" function. This is important to avoid motion distortion artefacts as can be seen with a *rolling shutter*.
GUI	Graphical user interface. A program interface that takes advantage of the computer's graphics capabilities to make the program easier to use.

H

High Gain	Mode in some Photonfocus cameras giving a 4x analog amplification of the sensor data.
Histogram	A graphical representation of the frequency of occurrence of each intensity or range of intensities (grey levels) of pixels in an image. The height represents the number of observations occurring in each interval. The middle of the histogram indicates the average grey value whilst the width of the histogram indicates the contrast range.
Hot pixels	Hot pixels are pixels which exhibit an excessively high *dark current* but otherwise behave as normal. These pixels appear as bright spots in the image and the effect is worse at longer integration times and higher temperatures (more appear).

I

Image lag	Common CCD problem. The amount of signal left in the photo element from the previous frame. Other common terms for image lag include residual image, ghosting, and

	frame to frame retention.
Image processing	Transformation of an input image into an output image with desired properties.
Integration time	See *Exposure time*
IR cut-off filter	Filter that cuts off the infra-red wavelengths (> ≈750 nm). Can help to increase contrast in visible light applications.

L

LEN	In CameraLink, Line enable. See *Line valid*.
LFSR	Linear feedback shift register. In Photonfocus cameras, an operation mode to output a constant pattern containing every grey level for debug reasons.
Line hopping	Special camera mode where only every n^{th} row is read out (n=1,2,3…). Can be used to readout sub-sampled images at higher speeds.
Line Pause	In Photonfocus cameras, a programmable delay before the first line and after every following line when reading out the image data. A small line pause is needed for correct sensor operation. Typically does not need to be adjusted by the user.
Line valid	In CameraLink, a handshake signal that indicates whether or not the camera is outputting a valid line of data.
Linear response	A linear relationship between the amount of light captured and the resulting output level. Compare to *Linlog* and *logarithmic response*.
LinLog™	Patented Photonfocus technology to increase dynamic range of CMOS cameras. Provides a logarithmic compression of the brightness level in the brighter parts of the image. The amount and turn-on point of the compression can be freely adjusted. Typically LinLog™ gives contrast in bright parts of the image that would otherwise be saturated white.
Linux	Free Unix-like operating system. Photonfocus cameras are supported under Linux subject to a Linux-compatible frame grabber. See the frame grabber compatibility list on the Photonfocus home page for details.
Logarithmic response	A logarithmic relationship between the amount of light captured and the resulting output level. It typically offers high dynamic range but non-uniform brightness resolution which is poor in bright parts of the image. Compare to *Linear*

	response, *LinLog*.
Look-up table	In some Photonfocus cameras, a table performing an arbitrary mapping of input digital numbers from the pixels to output digital numbers sent to the frame grabber. Is typically used to implement a transfer curve for contrast expansion.
LSB	Least significant bit. The bit in a binary number that represents the least significant value (typically the right-hand bit).
LUT	See *Look-up table*.
Lux	The SI unit of illuminance. Lux is a photometric unit and takes into account the sensitivity of the human eye; therefore it depends on the wavelength. One Lux is equal to one lumen per square meter.
LVAL	CameraLink signal. See *Line valid*
LVDS	Low-Voltage Differential Signalling. An electrical specification (EIA-644) for the transmission of digital data, which delivers high data rates while consuming significantly less power than other technologies.

M

Machine Vision	The automatic acquisition and analysis of images to obtain desired data for controlling a specific activity.
Master clock	Mode of some Photonfocus cameras, where the *pixel clock* can be provided externally to synchronise two or more cameras to the same pixel clock or to interface the camera to a special pixel clock.
MCLK	See *Master clock*.
MFD	See *Mount Flange Distance*.
Microbench	Versatile 4-rod-construction system that enables 3-dimensional opto-mechanical setups with highest precision and stability. All Photonfocus cameras are compatible to the Microbench system.
Modulation transfer function	The modulation transfer function (MTF) gives the variation of contrast with increasing *spatial frequency*. The better the modulation transfer function the better the image clarity. The ideal MTF can be predicted from the resolution and pixel pitch but the real MTF can diverge from this due to effects such as charge leakage between pixels. A good MTF is

	therefore one which is close to the MTF predicted by pixel geometry.
Mount Flange Distance	Optical distance from the camera mount flange to the image sensor's photo-sensitive surface.
MROI	See *Multiple ROI*
MSB	Most significant bit. The bit in a binary number that represents the most significant value (typically the left-hand bit).
MTF	See *Modulation Transfer Function*
Multiple ROI	The possibility to define several different *regions of interest* (ROI) which can be read out within a frame. Some Photonfocus cameras can handle up to 17 ROI. Please see the User's manual for limitations.
MV	See *Machine vision*.

N

Noise	Unwanted disturbances of the signal level containing no useful information. Noise can obscure small signals which are then said to be beneath the "noise floor". Major noise sources can be shot noise, device mismatches, reset noise and other electrical noise. See also *Fixed-pattern noise*, *PRNU* and *Temporal noise*.

O

OEM	Original Equipment Manufacturer.
Optical active area	The optical active area or the optical field of an image sensor is the physical size of the pixel matrix. It can be calculated by resolution * pixel pitch.

P

PFRemote	Software Tool (*GUI* and *SDK*) to configure and control the Photonfocus cameras.
Photo diode	A semiconductor diode that is explicitly designed as a photo detector. In CMOS imagers this is a silicon p-n junction which converts incoming optical power into an electrical current.
Photometry	Photometry is the science of measuring visible light in units that are weighted by the sensitivity of the human eye. Typical photometric units include lumens, lux and candelas. Compare to *Radiometry*.

Photon	The light quantum. The smallest possible "packet" of light energy at a given wavelength.
Pixel	Short for picture element. A photosensitive element on an image sensor; also, a smallest graphic element in an image.
Pixel clock	The pixel clock is a high frequency clock to determine when the data lines have valid data. Usually the pixel clock is generated by the camera and is received by the frame grabber.
Pixel pitch	The pixel pitch indicates the physical dimensions of one image *pixel*. See also *Fill factor* and *Optical active area*.
Pixel size	See *Pixel pitch*.
PRNU	Photo-Response Non-Uniformity. Variation in responsivity between pixels. This is a spatially correlated noise source similar to *fixed pattern noise* (FPN), which can be largely eliminated by a gain-offset correction. PRNU is typically given as the standard deviation of a 90% grey image after FPN has been removed.

Q

QNX	Real-time operating system that provides multitasking, priority-driven pre-emptive scheduling and fast context switching. Photonfocus cameras are supported under QNX subject to a QNX-compatible frame grabber. See the frame grabber compatibility list on the Photonfocus home page for details.
Quantum efficiency	Quantum efficiency indicates the efficiency of the conversion of photons to electron-hole pairs and the collection of these pairs into a useful electrical signal. Typically the quantum efficiency is the ratio between impinging photons on a pixel and the number of collected electrons. Sometimes the quantum efficiency of the photodiode by itself is indicated, sometimes the *fill factor* of the pixel is included.

R

Radiometry	Radiometry is the science of measuring light in fundamental physical units such as power (Watt) and energy (Joule). For CMOS sensors irradiance is typically of interest; this is measured in W/m^2. See *Photometry*.
Region of interest	A defined rectangular region in the image matrix which can

	be read out separately from the rest of the matrix. By reading out only this region, less data needs to be transferred and so frame rates can be dramatically increased.
Resolution, Greyscale	Number of grey levels used to represent pixel brightness. For example, 8 bits give 256 levels of grey; 10 bits give 1024 levels of grey. See also *Digital number*.
Resolution, Image	Number of pixels in the pixel array. Resolution is typically given in horizontal and vertical pixel numbers, e.g. 640x480 indicates 640 image columns, 480 image rows and 307,200 total pixels.
Responsivity	See *Sensitivity*.
ROI	See *Region of Interest*
Rolling Shutter	Rolling shutter is a type of *electronic shutter* which operates row-wise. As a result, the top rows in the image may be captured earlier than the bottom rows and the object may have moved in the mean time. This can give rise to motion distortion artefacts which could be avoided with a *global shutter*.

S

SDK	Short for Software Development Kit, a programming package that enables a programmer to develop applications for a specific platform. Typically an SDK includes one or more *APIs*, programming tools, and documentation.
Sensitivity	Measure of the ability of a sensor to detect light. Some camera manufacturers quote output signal level per input light level as sensitivity, others quote minimum detectable input light level. It is therefore important to consider the units, for example a "sensitivity" given in DN/W/cm^2 is of the first type, sometimes also called responsivity, while a "sensitivity" given in W/cm^2 is of the second type.
Shot noise	Noise arising due to quantum effects. This causes a fundamental physical limitation on noise performance of any image capture system because the light signal itself is the cause of this noise. For every N photons captured, there will be an associated noise of sqrt(N) photons standard deviation. A similar law applies to electrons. Shot noise of the input light is typically the largest source of temporal

	noise. See also *Temporal noise*, *Noise*.
Shutter	See *Electronic shutter*.
Skimming	Photonfocus technology to enhance detail in dark areas of an image. Skimming provides an adjustable level of in-pixel gain for low signal levels. Skimming can be used together with LinLog to give a smooth monotonic transfer function from high gain at low levels, through normal linear operation, to logarithmic compression for high signal levels.
Smear	Smear is a common problem for CCD sensors but not for CMOS sensors. It occurs when a bright object or light source is shot with the camera. This phenomenon is observed as a vertical or horizontal streak above and below the bright object or light source.
Spatial frequency	Refers to the periodicity with which the image intensity values change. Image features with high spatial frequency (such as edges) are those that change greatly in intensity over short image distances. Spatial frequency is often given in line-pairs per mm (lp/mm). 1 lp/mm is equivalent to one complete transition from black to white in the space of 1 mm.
Spectral response	Variation in sensitivity of the sensor with wavelength of the incoming light. The physics of CMOS devices typically gives a useful response to light in the range from near ultra-violet, across the visible range and into the near infra-red.
Storage node	In a global shutter sensor, location inside a pixel where the image is stored after the exposure has been ended by means of the global shutter. The image is “frozen” in the storage node until it is read out of the camera.
Storage node dark current	In a global shutter sensor, an unwanted signal which is added to the image stored in the *storage node* waiting to be read out. See also *Dark current*. The effect of storage node dark current is usually small compared to other unwanted signal sources.

T

Tap	In CameraLink, a tap is a data path transferring the image data. With every *pixel clock*, the digital value of one pixel is transferred. The tap width can be 8 bit, 10 bit or more, depending on the camera. Some cameras use multiple taps

	to increase speed. Inside the camera or for OEM-modules, CameraLink is not used and the number and width of taps can be different.
Temporal noise	The term temporal noise is typically used to cover all noise which is not correlated between images. *FPN* and *PRNU* are examples of correlated noise. Temporal noise can come from many sources in a camera system including shot noise, thermal noise, flicker, reset noise and ADC quantisation noise. Correlated noise can often be corrected, temporal noise is harder to correct. Temporal noise also varies with camera settings and illumination levels. Fortunately, temporal noise is typically smaller than correlated noise. See also *Shot noise*.
Triangulation	A method of determining distance by forming a right triangle consisting of a light source, camera and the object. The distance or range can be calculated if the camera to light source distance and the incident to reflected beam angle are both known.
Trigger	Trigger refers to the event that starts a new image acquisition. Usually several different trigger modes are provided. In free running / self triggered mode, the camera automatically captures and delivers a constant stream of images using preset values to determine the exposure time and frame rate. In external trigger modes the camera waits in an idle state for a trigger event before starting a new integration and readout cycle.

V

Visible Light	The region of the electromagnetic spectrum in which the human retina is sensitive, ranging from about 380 to 780 nm in wavelength.

W

Window of Interest	See *Region of Interest*

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4. Revision History

REV	Description of the modification	Date
1.0	Initial version	06/07/04

Table 1: Document revisions